BATTLESHIP TEXAS (BB-35)

STABILITY ASSESSMENT

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BATTLESHIP TEXAS (BB-35): STABILITY ASSESSMENT

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1. Introduction

Stability of a ship is analyzed in two configurations, undamaged and damaged. In the undamaged condition, the ship is assumed to have no flooding and, and in the case of a battleship, it will have two main hazards – hurricane force winds and capsizing in a high speed turn. For WW I-era battleships, the only credible hazard is hurricane force winds. In the damaged condition, the ship will have substantial water flooding the internal tanks of the ship and will be subject to two hazards – capsizing from off-center flooding and bodily sinkage if the amount of water is excessive.

The undamaged (intact) condition of the battleship Battleship TEXAS (BB-35) in its present moored configuration and in a mud berth is considered to be stable against the likeliest threat, i.e., hurricane force winds.

Damage stability is not currently considered to be a problem as the battleship is in shallow water, partly grounded and moored to a set of monopiles. In addition, the large beam of the ship, coupled with the shallowness of the slip means that capsizing is impossible. Damage stability may become a significant problem when the ship is floated or towed out of the slip as there is an opportunity for large amounts of water to enter the ship from the bottom and to up-flood into large, possibly off-center spaces.

2. Intact and Damage Stability Assessment

2.1 Intact Stability Assessment

The best method to determine the stability characteristics of any ship is the naval architectural inclining experiment exercise. This procedure is used to determine the weight and the center of gravity of the ship in three planes, vertically, horizontally and transversely. From this experiment the actual condition of the ship under any loading condition can be calculated and it can be determined if it is safe to operate. The experiment is complicated and requires careful attention to details in order to produce reliable results. BB-35 was never given this expensive and time consuming inclining experiment exercise, a practice which only started with the BB-38 and other later-built US Navy Battleships.

The stability can be approximated in a simpler exercise by timing the rate at which the ship rolls. Once the ship is made to roll 4 or 5 degrees, the roll period can be measured with a stop watch. This method was used by the US Navy to determine the stability of the USS COLORADO (BB-45) in 1944, and also the USS AMERICA (CV-66), which was sallied by Newport News, with a 500 ton ingot on the edge of the flight deck. The same method was used to determine the stability of USS TEXAS after the 1989 rebuilding.

With the roll period, formulas are available to calculate the ship's GM (metacentric height; see Figure 1) and therefore the vertical height of the center of gravity.

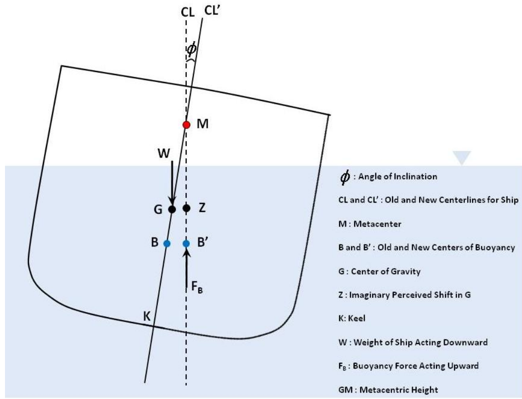

Figure 1 Sketch of Ship's Bodyplan View for Calculating Metacentric Height

The estimated stability condition of BB-35, compared to the Light Ship Condition for the more modern battleships which did get an inclining experiment during the war, is shown in Table 1:

Table 1 Comparison of Battleship TEXAS (BB-35) with Modern Battleships[1]

Hull Number	Name	Date	Weight (Long Tons)	Vertical Center of Gravity (KG; Feet)	Metacentric Height (GM; Feet)
BB-35	TEXAS		25,119	34.38	12.55
BB-38	PENNSYLVANIA	1/10/1943	30,265	34.55	8.86
BB-41	MISSISSIPPI	7/2/1944	30,955	36.39	7.91
BB-45	COLORADO	4/24/1944	31,116	34.53	11.02
BB-38	PENNSYLVANIA	5/2/1945	31,148	34.65	7.95
BB-46	MARYLAND	7/29/1945	30,265	36.07	9.79
BB-48	WEST VIRGINIA	4/12/1946	31,606	35.82	13.44

The KG was determined in the 1989 study for a roll period of 12.16 seconds based on a partial load condition found in the 5 Jan 1927 records. The displacement of 25,119 tons would result in the following parameters:

- KM (Vertical Metacentric Height from Keel)= 46.93 feet
- KG=34.38 feet
- GM (GM = KM –KG)=12.55 feet

Although the large GM seems inconsistent with the values for much larger ships, this confirms the complaints made by the operating forces about the Battleship TEXAS (BB-35) being very stiff and an uncomfortably sharp rolling ship.

2.2 Damage Stability Assessment

[1] "U.S. BATTLESHIPS, AN ILLUSTRATED DESIGN HISTORY", Norman Friedman, Naval Institute Press, Annapolis, MD, pp. 436 – 445, 1985.

As originally built, the ship was subdivided into many small compartments and tanks intended to contain various items of loading. For the volume in the lower part of the ship, many small tanks were installed to handle fuel, drinking water, lube oil and boiler feed water. These tanks were deliberately made small so that the emptying or filling of a single tank or group of tanks would not have a noticeable effect on the ship. When the ship became a museum vessel and all of these tanks were emptied, it became clear that periodic surveys of these tanks would be necessary to determine if they contained unexpected liquids. Since museum ships do not have the manpower resources comparable to when the ship was an active battleship, the tank survey became a significant maintenance problem. In order to reduce the survey and maintenance teams' requirements, holes were cut in the lower part of several tanks in order to form a single group, i.e., the tanks were "communized", requiring just a single tank to be opened. The groups were selected so that the unexpected flooding of any of the groups would not have a significant effect on the ship's safety.

The damage stability calculations provided herein are based on an examination of the ship to determine where the ship may be vulnerable to flooding and then to calculate the effects on the ship from flooding of a space. The immediate effect of flooding will be an increase in weight of the ship, which will cause the draft to increase. In addition, if the flooded compartment is at one end of the ship or located off to one side, it will cause the ship to lean or list in that direction. Based on precise measurements of the ship's decks and bulkheads, it is possible to determine what changes in draft, trim and list will occur if certain spaces become flooded. It is emphasized that the calculations do not show which compartments will flood but they do predict what will happen to the ship if the compartments become flooded. If a chosen source of flooding does not cause an immediate danger to the ship then the process is repeated to determine if two cases of flooding represent a danger. If the ship can survive this flooding the process is repeated, adding more flooding until all of the vulnerable spaces are included. For the battleship, the inherently large stability means that it would take a combination of many flooding conditions before the ship would become severely inconvenienced, but there are combinations which could represent a problem.

The stability calculations were performed for two configurations of the vessel:

- Configuration 1 – Current configuration of vessel with Blister Tanks (Vessel Displacement = 25119 LT)
- Configuration 2 – Original configuration of vessel without Blister Tanks (Vessel Displacement = 24637 LT)

Flooding scenarios considered included flooding (from the bottom of the space to the waterline) of the Blister Tanks, Aft Trim Tanks (D-12 and D-13), Boiler Rooms (B-2, B-3 and B-4) and Engine Rooms (C-1 and C-2). Table 2 and Table 3 show the various flooding scenarios (see also Figure 2 through Figure 7) and the corresponding changes in the vessel trim, forward and aft drafts, and list. The computational output is provided in Appendix A (for Configuration 1) and Appendix B (for Configuration 2).

Table 2 Flooding Scenarios and Results for Vessel with Blister Tanks

Configuration No. 1 - Battleship TEXAS BB-35 Stability Assessment (With Blister Tanks)						
Scenario No.	Scenario Description	List (Deg)	Midship Draft (ft)	Trim (ft)	Forward Draft (ft)	Stern Draft (ft)
1	Intact Stability (Displacement = 25119 LT)	0.0	24.5	3.3	22.8	26.1
1A	Blister Tanks Flooded	0.0	26.6	4.6	24.3	28.9
1B	Flood Blister Tanks and Aft Trim Tanks	0.0	26.8	6.8	23.4	30.2
1C	Flood Blister Tanks, Aft Trim Tanks and Both Engine Rooms	0.0	28.5	12.1	22.4	34.5
1D	Flood blister Tanks, Aft Trim Tanks, Both Engine Rooms and Three Boiler Rooms	0.0	31.4	8.1	27.3	35.4
1E	Flood Blister Tanks, Aft Trim Tanks, Three Boiler Rooms and Only Starboard Engine Rooms (To Maximize List)	4.8	30.6	5.5	27.8	33.3

Table 3 Flooding Scenarios and Results for Vessel without Blister Tanks

Configuration No. 2 - Battleship TEXAS BB-35 Stability Assessment (Blister Tanks Removed)						
Scenario No.	Scenario Description	List (Deg)	Midship Draft (ft)	Trim (ft)	Forward Draft (ft)	Stern Draft (ft)
2	Intact Stability (Displacement = 24637 LT)	0.0	26.1	4.8	23.7	28.5
2B	Flood Aft Trim Tanks	0.0	26.3	7.0	22.9	29.8
2C	Flood Aft Trim Tanks and Both Engine Rooms	0.0	28.0	12.3	21.8	34.1
2D	Flood Aft Trim Tanks, Both Engine Rooms and Three Boiler Rooms	0.0	30.9	8.3	26.7	35.0
2E	Flood Aft Trim Tanks, Three Boiler Rooms and Only Starboard Engine Rooms (To Maximize List)	5.2	30.1	5.7	27.2	32.9

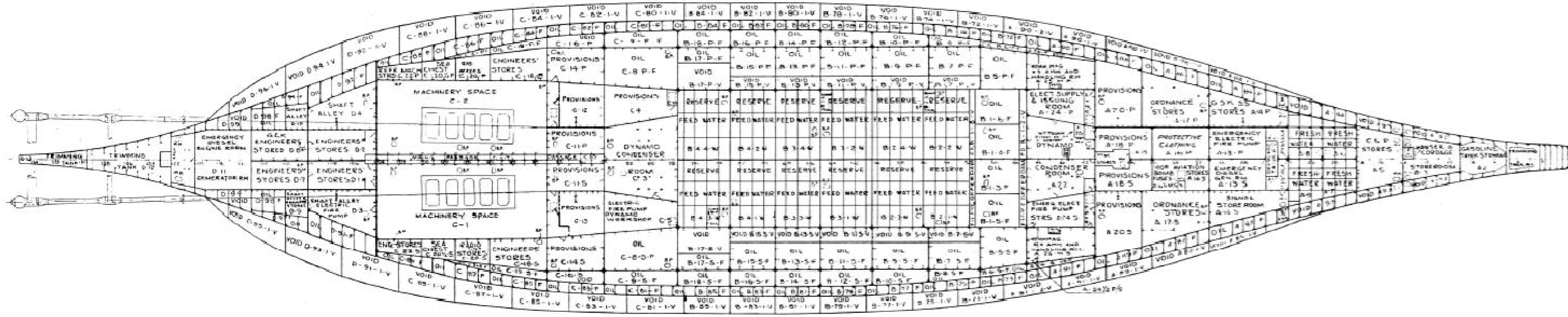

Figure 2 Undamaged/Intact Vessel Tankage Plan

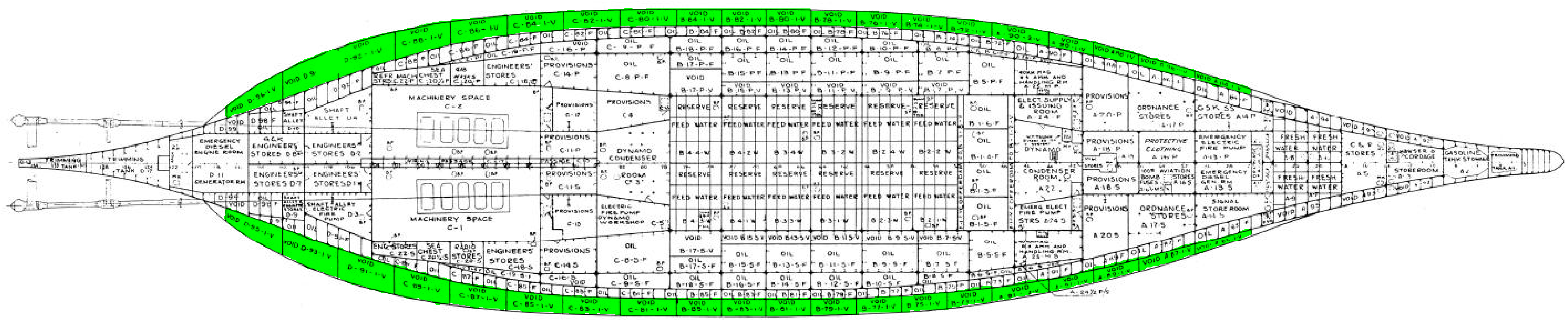

Figure 3 Vessel Tankage Plan Showing Flooded Blister Tanks (Green)

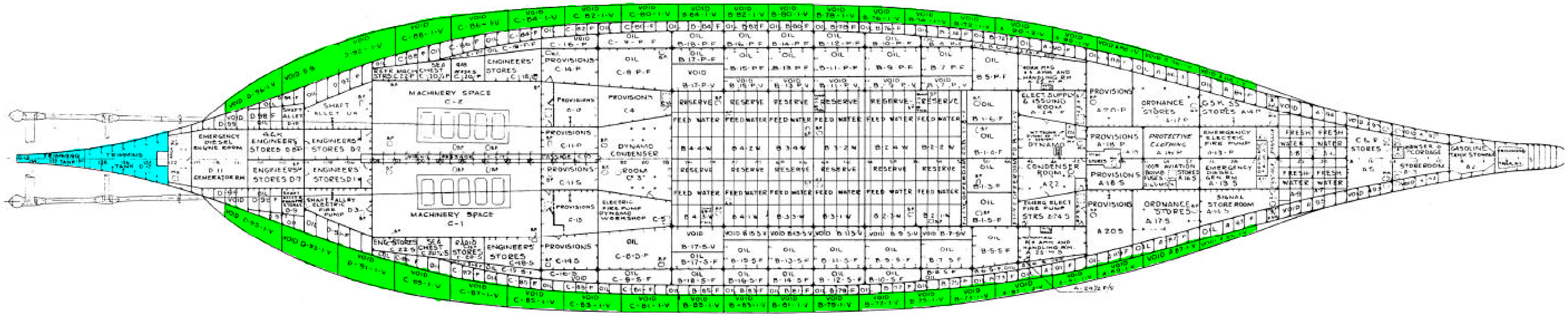

Figure 4 Vessel Tankage Plan Showing Flooded Blister Tanks (Green) and Aft Trim Tanks (Blue)

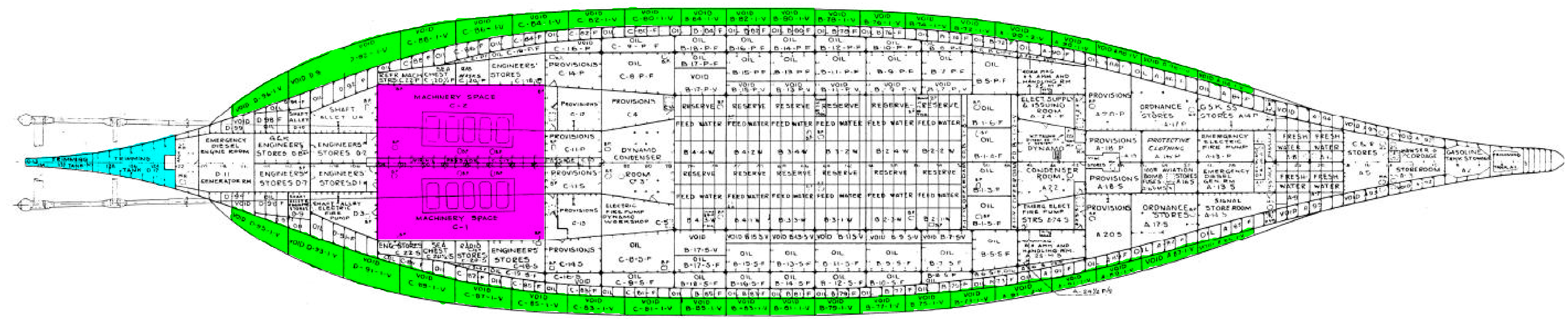

Figure 5 Vessel Tankage Plan Showing Flooded Blister Tanks (Green), Aft Trim Tanks (Blue) and Engine Room Spaces (Magenta)

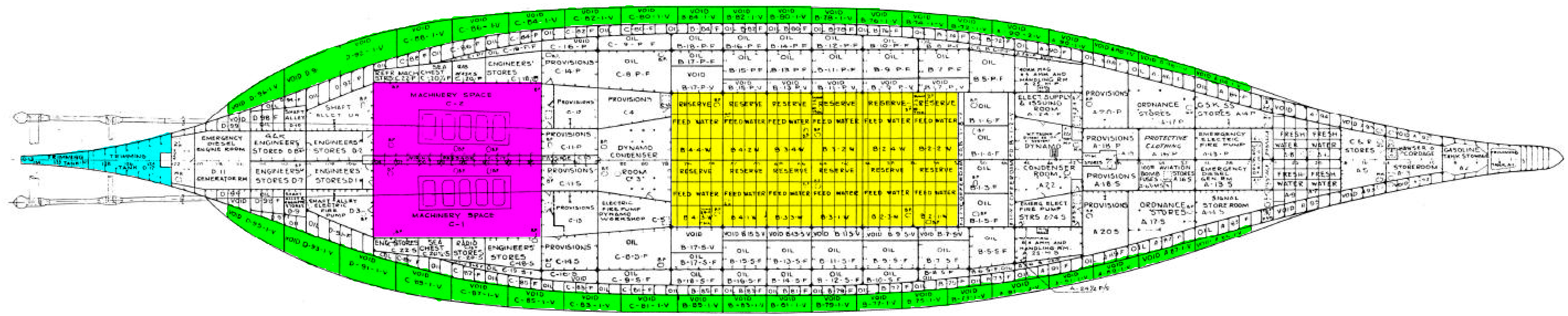

Figure 6 Vessel Tankage Plan Showing Flooded Blister Tanks (Green), Aft Trim Tanks (Blue), Engine Rooms (Magenta) and Boiler Room Spaces (Yellow)

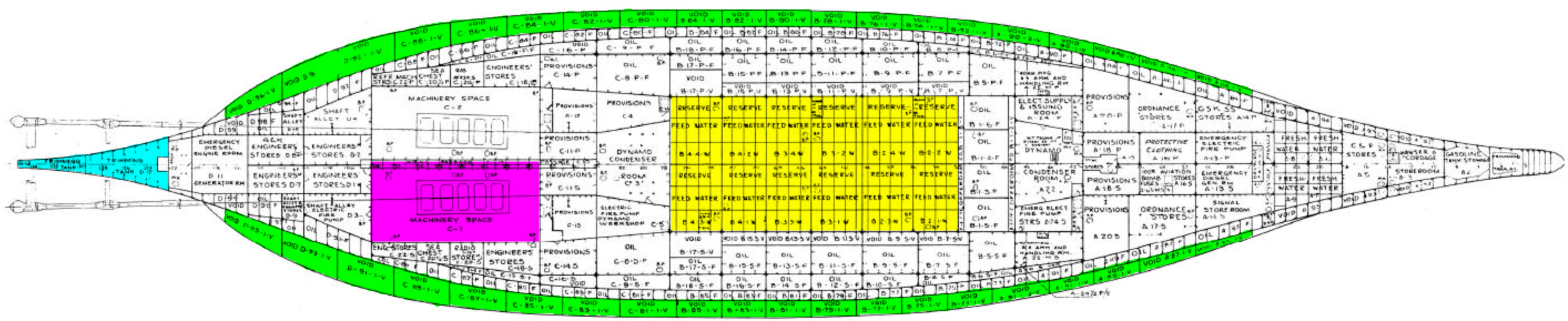

Figure 7 Vessel Tankage Plan Showing Flooded Blister Tanks (Green), Aft Trim Tanks (Blue), Engine Room (Only Starboard Side; Magenta) and Boiler Room Spaces (Yellow)

3. Structural Assessment and Recommendations

The battleship was originally built with two four-foot tall layers in the inner bottom. These layers contained the tanks for the drinking water, the boiler feed water and the diesel fuel for the emergency generator. Following the 1926 conversion from coal to fuel oil, additional tanks were needed to store the oil. The two lower layers of the hull formed a honeycomb arrangement (see Figure) to separate the liquids in the tanks and to provide foundations for the machinery and ordnance higher in the ship.

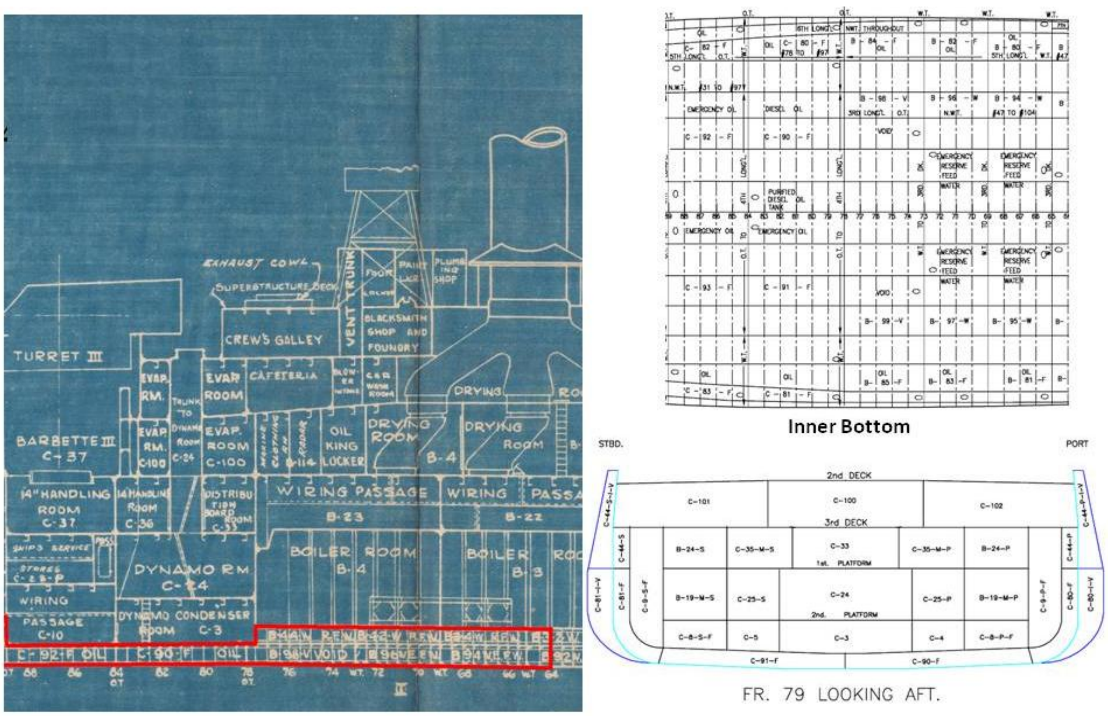

Figure 8 Honeycomb Arrangement for Bottom Layers of the Hull (From TPWD Drawings)

This structure has been substantially eroded and probably will not be strong enough to support the upper part of the ship without significant plate replacement. Because the structure will not be required for use as tankage, it does not need to be as finely divided. Replacement of the bottom and side plating, the center vertical keel, the lower 8 feet of the main subdivision bulkheads and some longitudinal and transverse frames, should be sufficient. The replaced grid structure must be capable of transmitting the approximately 20,000 tons of the upper hull without deforming. Under the machinery spaces, the frames would need to be eight feet tall to support the engine and boiler foundations. In the rest of the ship, the grid would only need to be four feet tall. At the stern, in the area of the steering gear rooms, it may be necessary to carry the new steel to the underside of the second deck in order to restore enough strength prevent the aft end of the ship from sagging.

Replacement of the outer plating over the 1926 torpedo blister tank is recommended to maintain the form of the underwater hull which will be visible no matter which dry-berthing plan is selected. The plating could be reduced from the original 5/8 inch plate as the blister tank does not contribute significantly to the overall structure.

4. Summary

The existing monopiles were installed to maintain the position of the ship with respect to forward and aft movement, or swaying from side to side. The battleship might be able to sustain the condition of again being afloat if the slip was dredged. However, with the towing forces necessary to move the ship in its current condition, it seems likely that the plate separations throughout the ship's bottom would permit massive amounts of water to enter the battleship, causing progressive flooding of the ship due to loss of watertight integrity of transverse bulkheads and possible collapse of internal structure.

Unless the underwater hull and interior scantlings are significantly reinforced to restore a substantial amount of structural integrity, moving the ship into the Houston Ship Channel would represent an extremely hazardous undertaking. The potential loss or damage to the ship would also impact navigation traffic in the channel adversely.

The Project Manager, Mr. Stratford Morss, and Marine Surveyor and Chief Inspector for the project, Mr. Dick Frentzl, present at the time of last dry-docking of the ship in 1989, stated to Mr. Lombardi that all blister tankage was made watertight during the dry-docking. Based on the hull inspection and review of tank soundings by Ocean Technical Services, the blister tanks may have lost their watertight integrity and the ship may be heavier than in 1989. Blister tankage soundings were provided by ship staff at the time of survey. The naval architect and marine surveyor utilized the “INNER BOTTOM TANK SOUNDINGS 5-2009” drawing and current ship sounding table (developed by onboard TPWD staff) for all tankage provided to reach the conclusions stated herein. The blister tanks, both port and starboard, for the most part are severely deteriorated, may have lost their water-tight integrity, and may not be considered totally buoyant. Depending upon prioritization for upcoming ship repairs, an inspection of the blister tankage would be warranted. The loss of watertight integrity with regard to the blister tankage affect both port and starboard sides.

In summary, based on an assessment of the stability as well as general structural condition of the ship, the following recommendations are provided with regard to any dredging (of the current slip) or towing of the ship:

- The need for monitoring of the ship will be required during any dredging at the slip or towing of the ship, due to the very poor material condition of the ship. Dredging requirements for the ship in its current slip (during temporary construction repairs), during towing and relocation to dry-berth, are outside the scope of this report and will be addressed separately.
- In a floating condition, there is a significant danger of loss of stability for the vessel due to the possibility of up-flooding into large off-center spaces.
- The removal of blister tanks can be expected to lead to an increase in the trim and drafts of the vessel in its intact/undamaged condition due to a reduction in the waterplane area and loss of buoyancy.
- Flooding scenarios considered here indicate that large (several feet, degrees) increases in draft/trim and/or list of the vessel can occur for vessel configurations with or without blister tanks.
- Existing and supplemental pumping capability will be required onboard to keep the vessel stabilized whilst in a ‘floating’ condition even after temporary repairs have been completed.
- The vessel’s bitts and chocks on main deck will require strengthening before the vessel can be towed.
- The underwater hull and interior scantlings need to be significantly reinforced to restore a substantial amount of structural integrity before moving the ship into the Houston Ship Channel.
- The use of monopiles remains necessary should the vessel be moored to a temporary location as the vessel’s blister tankage is not capable of supporting the side loads of the ship against fendering.

Appendix A

Ship Hull Characteristics Program Computational Output for Flooding Scenarios in Configuration 1 (current configuration of vessel with Blister Tanks)

Run Date : 20-MAY-11   Run Date : 20-MAY-11

```
                  SSSS     HH      HH     CCCC     PPPPPPP
                 SSSSSS    HH      HH    CCCCCC    PPPPPPPP
               SS    SS   HH      HH   CC    CC   PP     PP
             SS      SS  HH      HH  CC      CC  PP      PP
             SS         HH      HH  CC      CC  PP     PP
             SSSS      HHHHHHHHHH  CC          PPPPPPPP
              SSSS    HHHHHHHHHH  CC          PPPPPPP
          SS      SS   HH      HH  CC      CC  PP
         SS       SS  HH      HH  CC      CC  PP
         SS    SS   HH      HH   CC    CC   PP
         SSSSSS    HH      HH    CCCCCC    PP
          SSSS     HH      HH     CCCC     PP
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SHIP HULL CHARACTERISTICS PROGRAM

Version : 4.33.12
Version Date : 17-Feb-04
Configured By : John Rosborough

Run Date : 20-MAY-11   Run Date : 20-MAY-11

S H C P Limits List

Main Hull & Appendage Limits (HULL)		DECK, LQLOAD, SUB & COMP Limits	
Max # Points per Station	100	Max # Decks Described	30
Max # Breakpoints / Station	48	Max # Points / Decks	151
Max # Stations per Hull	151	Max # Fixed Fl /Lqd Ld Spaces	1000
Max # Appendages	500	Max # Subdivisions	200
Max # Offsets Referenced	50	Max # Subdivision Space IDs	5000
Max # Stations (total)	7702	Max # Compartments Described	5000
Max # Points in SDT	4000000	Max # Compts/Damag Groups	1000

Hydrostatic Limits (HYDRO)		Trim Lines Limits (TRIML)	
Max # Waterlines (w/ DWL)	101	Max # Compartments Described	41
Max # Trims	7	Max # Compts / Damage Group	15
Max # Composite BonJean Stats	100		

Longitudinal Strength (STRNGH)		Floodable Length Limits (FLOODL)	
Max # Weight Stations	75	Max # Permeabilities	7
		Max # Longitudinal Increments	40

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                                    |  Max # Bulkheads (+ FP & AP)       52

************************************|************************************
  Limiting Draft Limits       (DRAFTL) | Intact Stability Limits     (INTACT)
  ---------------------------------- | ----------------------------------
   Max # Compartments Described      41|  Max # Displacements / Drafts       7
   Max # Compts / Damage Group       15|  Max # LCGs / Trims                 7
   Max # Pole Heights                 7|  Max # Angles of Heel              20

************************************|************************************
  Damage Cross Curves          (DAMXC) | Damage Transverse Stability  (DAMTS)
  ---------------------------------- | ----------------------------------
   Max # Angles of Heel              20|  Max # Angles of Heel              30
   Max # Drafts                       7|
   Max # Trims                        7|

************************************|************************************
  Intact Stability on Waves  (INTACTW) | Tank Capacities / Free Surf.  (TANK)
  ---------------------------------- | ----------------------------------
   Max # Angles of Heel              20|  Max # Angles of Heel              50
                                     |  Max # Trims                       30
                                     |  Max # Capac/Sndings Computed     100
                                     |  Max # Sounding Tube Points        50

************************************|************************************
   Damage Longitudinal Stab.   (DAMLS) |  Damageable Length       (DAMLNGTH)
  ---------------------------------- | ----------------------------------
   Max # Angles of Trim              30|  Max # Permeabilities               7
                                     |  Max # Angles of Heel              20
                                     |  Max # Bulkheads (+ FP & AP)       52
                                     |  Max # Longitudinal Increments     40

************************************|************************************
1SHIP- BB 35 Original Hull    05/20/11   SERIAL #- 6134  DATE:20-MAY-11 PAGE:   3

                              VESSEL DESIGN CONDITION

 DESIGN DISPLACEMENT          24637.000 TONS SW at DENSITY =     35.000 FT3/TON
 DESIGN DRAFT   (+ ABOVE BL)     26.103 FT |
 DESIGN LCG     (+ FWD MID)      -4.080 FT | DESIGN LCB  (+ F MID)      -4.080 FT
 DESIGN VCG     (+ ABOVE BL)      0.000 FT | DESIGN VCB  (+ ABL)        14.192 FT
 DESIGN TCG     (+ STBD)          0.000 FT | DESIGN TCB  (+ STBD)        0.000 FT
 DESIGN TRIM    (+ BY STERN)      4.647 FT | DESIGN LIST (+ STBD)        0.000 DEG

 LENGTH OVERALL                 565.000 FEET
 LENGTH BETWEEN PERPENDICULARS  565.000 FEET
 LENGTH ON DESIGN WATERLINE     565.000 FEET

 STATION OF MAX AREA (AT DWL)   289.806 FEET FROM FP
 BEAM AT STATION OF MAX AREA     95.296 FEET
 SECTION AREA COEFFICIENT        0.9945
 PRISMATIC COEFFICIENT           0.6155
 BLOCK COEFFICIENT               0.6121

 Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iterations           =        50
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                 Approximate Bounding Cube Values:
       -----------------------------------------------------
        Forward X location              0.000 Ft (+ Aft FP)
        After   X location            565.000 Ft (+ Aft FP)
        PORT    Y value on Station    -79.812 Ft
        STBD    Y value on Station     79.812 Ft
        Lowest  Z value on Station      0.000 Ft (+ Abv BL)
        Highest Z value on Station     53.231 Ft (+ Abv BL)

   KK     3 NO Main Hull INITIAL & INTERPOLATED OFFSETS Printed
   IPLOT  0 NO PLOTS
   NPU      Plots will be SHCP NEUTRAL PLOTFILE unformatted
   PWIDTH   Plotter Width (inches) set to :    30.000
   PBORDR   Plot Border (inches) set to   :     1.000
   POHANG   Fraction of LBP for overhang  :     0.150
   KKAP   0 Print Appendage INITIAL and INTERPOLATED OFFSETS
   IPLTAP 0 NO Appendage PLOTS
   IPLCON 0 Connection from Station ENDS to Centerline & DAE SHOWN
   MSGSAV 0 Do not save HULL/APPENDAGE Evaluation Messages if Successful
   IUNIT  0 Input/Output units selected are ENGLISH-ENGLISH

                  HULL & APPENDAGE PROPERTIES AT DESIGN CONDITION
                                                          +STBD   +ABL
+AFT FP
   N  R        TITLE                     VOLUME    DISPL    TCB     VCB
LCB  TYPE  SYM
   0 " " Main Hull                    861584.94  24616.7   0.000  14.195
286.485  OFF BOTH
   1     RUDDER                          320.00      9.1   0.000   8.000
548.000  PNT
   2     STARBOARD BILGE KEEL            195.00      5.6  55.000  12.000
282.500  PNT
   3     PORT BILGE KEEL                 195.00      5.6 -55.000  12.000
282.500  PNT
 Hull & Appendage Volume (Ft^3)       862294.94
      Displacement (Tons)                      24637.00
           Transverse Moment (Ft-Tons)                     0.00
                Vertical Moment (Ft-Tons)                     349652.06
                     Longitudinal Moment (Ft-Tons)
7060473.50

       2649 Entries used in SDT out of a maximum of   4000000
1SHIP- BB 35 Original Hull    05/20/11   SERIAL #- 6134  DATE:20-MAY-11 PAGE:   4
  INFO - The following Point Volumes are close to or exceed volumetric tolerance:
8.62294960
 1 RUDDER                       Volume: 320.000000  Weight: 9.14285755
 2 STARBOARD BILGE KEEL         Volume: 195.000000  Weight: 5.57142878
 3 PORT BILGE KEEL              Volume: 195.000000  Weight: 5.57142878
1SHIP- BB 35 Original Hull    05/20/11   SERIAL #- 6134  DATE:20-MAY-11 PAGE:   5

                         INPUT COMPARTMENT DESCRIPTIONS

  ID        NAME           SYM PERM   X1D    X2D      Y1D      Y2D      Z1D
Z2D  ROFF

 100 Fwd Boiler Rm B-2       0 0.90 208.00 244.00     NONE    30.00     8.00
28.00   0
```

200	Mid Boiler Rm B-3	0	0.90	244.00	276.00	NONE	30.00	8.00	28.00	0
300	Aft Boiler Rm B-4	0	0.90	276.00	308.00	NONE	30.00	8.00	28.00	0
400	Stbd Engine Room	1	0.85	356.00	416.00	2.00	30.00	4.00	28.00	0
450	Port Engine Room	-1	0.85	356.00	416.00	2.00	30.00	4.00	28.00	0
800	Trim Tank D-12	0	0.95	488.00	518.00	NONE	NONE	4.00	20.00	0
810	Trim Tank D-13	0	0.95	518.00	540.00	NONE	NONE	10.00	20.00	0
998	INTACT STABILITY	0	0.10	282.50	283.50	NONE	0.10	NONE	0.10	0

DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

CONDITION 1

INTACT STABILITY

FREE FLOODED SPACES INCLUDED:
998

SHIP PROPERTIES BEFORE DAMAGE

DISPL	LCG	POLE HT	TCB	LIST	TOLVOL	TOLLBP	MAXITER
24637.00	-4.080	34.84	0.0000	0.000	0.000010	0.000005	20

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF
TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	0.000	0.000	14.194	-4.256	26.100	4.783
			5.00	0.417	2.217	14.290	-4.252	26.090	4.727
			10.00	0.859	4.444	14.584	-4.243	26.061	4.551
			15.00	1.371	6.712	15.088	-4.228	26.023	4.237
			20.00	1.952	9.004	15.811	-4.207	25.957	3.786
			25.00	2.631	11.328	16.774	-4.181	25.851	3.183
			30.00	3.242	13.517	17.911	-4.159	25.712	2.638
			35.00	3.359	15.205	18.982	-4.148	25.576	2.419
			40.00	2.997	16.432	19.920	-4.144	25.446	

2.431

45.00	2.279	17.327	20.736	-4.144	25.317

2.566

DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

CONDITION 2

Add Flooding in After Trim Tanks

FREE FLOODED SPACES INCLUDED:
800 810

SHIP PROPERTIES BEFORE DAMAGE

DISPL	LCG	POLE HT	TCB	LIST	TOLVOL	TOLLBP	MAXITER
24637.00	-4.080	34.84	0.0000	0.000	0.000010	0.000005	20

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF
TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	0.000	0.000	14.379	-4.332	26.340	6.965
			5.00	0.442	2.226	14.477	-4.330	26.331	6.918
			10.00	0.909	4.462	14.771	-4.320	26.306	6.757
			15.00	1.446	6.739	15.277	-4.304	26.271	6.468
			20.00	2.051	9.039	16.003	-4.282	26.212	6.060
			25.00	2.753	11.371	16.971	-4.254	26.117	5.507
			30.00	3.348	13.535	18.093	-4.231	26.018	5.108
			35.00	3.456	15.204	19.152	-4.221	25.937	5.078
			40.00	3.089	16.418	20.080	-4.219	25.866	5.323
			45.00	2.373	17.306	20.890	-4.221	25.802	5.725

DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

CONDITION 3

Add Flooding in Both Engine Rooms

FREE FLOODED SPACES INCLUDED:
800 810 400 450

SHIP PROPERTIES BEFORE DAMAGE

DISPL	LCG	POLE HT	TCB	LIST	TOLVOL	TOLLBP	MAXITER
24637.00	-4.080	34.84	0.0000	0.000	0.000010	0.000005	20

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF
TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	0.000	0.000	15.407	-4.503	27.956	12.308
			5.00	0.554	2.248	15.505	-4.500	27.949	12.270
			10.00	1.097	4.472	15.797	-4.487	27.902	12.062
			15.00	1.678	6.707	16.293	-4.464	27.833	11.703
			20.00	2.345	8.985	17.011	-4.434	27.750	11.224
			25.00	3.043	11.237	17.943	-4.403	27.668	10.784
			30.00	3.531	13.234	18.980	-4.383	27.689	10.804
			35.00	3.593	14.796	19.973	-4.376	27.800	11.259
			40.00	3.201	15.928	20.838	-4.378	27.937	12.013
			45.00	2.470	16.749	21.584	-4.384	28.098	12.962

DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

CONDITION 4

Add Flooding in all three Boiler Rooms

FREE FLOODED SPACES INCLUDED:
800 810 400 450 300 200 100

SHIP PROPERTIES BEFORE DAMAGE

DISPL	LCG	POLE HT	TCB	LIST	TOLVOL	TOLLBP	MAXITER
24637.00	-4.080	34.84	0.0000	0.000	0.000010	0.000005	20

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF

TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	0.000	0.000	16.777	-4.347	30.857	8.300
			5.00	0.679	2.253	16.875	-4.343	30.854	8.273
			10.00	1.318	4.455	17.165	-4.339	30.793	8.265
			15.00	1.941	6.617	17.644	-4.328	30.666	8.139
			20.00	2.629	8.805	18.335	-4.311	30.513	7.903
			25.00	3.218	10.853	19.181	-4.302	30.436	7.983
			30.00	3.542	12.605	20.091	-4.302	30.560	8.525
			35.00	3.545	14.024	20.992	-4.310	30.885	9.372
			40.00	3.147	15.062	21.787	-4.321	31.310	10.440
			45.00	2.446	15.818	22.481	-4.336	31.837	11.704

DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

CONDITION 5

Remove Flooding from Port Engine Room

FREE FLOODED SPACES INCLUDED:
800 810 400 300 200 100

SHIP PROPERTIES BEFORE DAMAGE

DISPL	LCG	POLE HT	TCB	LIST	TOLVOL	TOLLBP	MAXITER
24637.00	-4.080	34.84	0.0000	0.000	0.000010	0.000005	20

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF
TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	-0.635	-0.635	16.152	-4.269	30.056	5.690
			5.00	-0.024	1.602	16.249	-4.267	30.042	5.675

```
                           10.00   0.548   3.784  16.537  -4.264   29.956
5.679
                           15.00   1.158   5.973  17.022  -4.257   29.842
5.615
                           20.00   1.864   8.212  17.729  -4.245   29.717
5.461
                           25.00   2.571  10.395  18.632  -4.237   29.622
5.449
                           30.00   3.013  12.274  19.608  -4.237   29.703
5.866
                           35.00   3.086  13.768  20.558  -4.247   29.970
6.601
                           40.00   2.745  14.864  21.397  -4.261   30.345
7.590
                           45.00   2.109  15.681  22.141  -4.277   30.834
8.767
  INVALID COMMAND ENTRY: END
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Appendix B

Ship Hull Characteristics Program Computational Output for Flooding Scenarios in Configuration 2 (original configuration of vessel without Blister Tanks)

```
 SHIP- BB 35 Original Hull    05/20/11                 DATE:20-MAY-11 PAGE:   1

 Run Date : 20-MAY-11                                   Run Date : 20-MAY-11

                         SSSS     HH       HH      CCCC     PPPPPPP
                        SSSSSS    HH       HH     CCCCCC    PPPPPPPP
                      SS    SS   HH       HH    CC    CC   PP     PP
                    SS      SS  HH       HH   CC      CC  PP      PP
                    SS         HH       HH   CC      CC  PP      PP
                    SSSS      HHHHHHHHHH   CC          PPPPPPPP
                     SSSS    HHHHHHHHHH   CC          PPPPPPP
                SS     SS   HH       HH  CC      CC  PP
               SS      SS  HH       HH  CC      CC  PP
               SS    SS   HH       HH   CC    CC   PP
               SSSSSS    HH       HH    CCCCCC    PP
                SSSS     HH       HH     CCCC     PP


                     SHIP HULL CHARACTERISTICS PROGRAM
                     -    -    -                -

                                Version : 4.33.12
                           Version Date : 17-Feb-04
                          Configured By : John Rosborough

 Run Date : 20-MAY-11                                   Run Date : 20-MAY-11
1SHIP- BB 35 Original Hull    05/20/11   SERIAL #- 6134  DATE:20-MAY-11 PAGE:   2
                               S H C P  Limits List
 *************************************|*************************************
 *************************************|*************************************
  Main Hull & Appendage Limits  (HULL) | DECK, LQLOAD, SUB & COMP Limits
  ------------------------------------ | ------------------------------------
   Max # Points per Station        100|  Max # Decks Described              30
   Max # Breakpoints / Station      48|  Max # Points / Decks              151
   Max # Stations per Hull         151|  Max # Fixed Fl /Lqd Ld Spaces   1000
   Max # Appendages                500|  Max # Subdivisions               200
   Max # Offsets Referenced         50|  Max # Subdivision Space IDs     5000
   Max # Stations (total)         7702|  Max # Compartments Described    5000
   Max # Points in SDT         4000000|  Max # Compts/Damag Groups       1000
 *************************************|*************************************
 *************************************|*************************************
  Hydrostatic Limits           (HYDRO) | Trim Lines Limits           (TRIML)
  ------------------------------------ | ------------------------------------
   Max # Waterlines (w/ DWL)       101|  Max # Compartments Described      41
   Max # Trims                       7|  Max # Compts / Damage Group       15
   Max # Composite BonJean Stats   100|
 *************************************|*************************************
  Longitudinal Strength       (STRNGH) | Floodable Length Limits     (FLOODL)
  ------------------------------------ | ------------------------------------
   Max # Weight Stations            75|  Max # Permeabilities               7
                                      |  Max # Longitudinal Increments     40
                                      |  Max # Bulkheads (+ FP & AP)       52
 *************************************|*************************************
  Limiting Draft Limits       (DRAFTL) | Intact Stability Limits     (INTACT)
  ------------------------------------ | ------------------------------------
   Max # Compartments Described     41|  Max # Displacements / Drafts       7
   Max # Compts / Damage Group      15|  Max # LCGs / Trims                 7
   Max # Pole Heights                7|  Max # Angles of Heel              20
 *************************************|*************************************
  Damage Cross Curves          (DAMXC) | Damage Transverse Stability  (DAMTS)
  ------------------------------------ | ------------------------------------
   Max # Angles of Heel             20|  Max # Angles of Heel              30
   Max # Drafts                      7|
```

```
  Max # Trims                        7|
**************************************|**************************************
 Intact Stability on Waves  (INTACTW) | Tank Capacities / Free Surf.  (TANK)
 ------------------------------------ | ------------------------------------
  Max # Angles of Heel              20|  Max # Angles of Heel              50
                                      |  Max # Trims                       30
                                      |  Max # Capac/Sndings Computed     100
                                      |  Max # Sounding Tube Points        50
**************************************|**************************************
  Damage Longitudinal Stab.   (DAMLS) |  Damageable Length       (DAMLNGTH)
 ------------------------------------ | ------------------------------------
  Max # Angles of Trim              30|  Max # Permeabilities               7
                                      |  Max # Angles of Heel              20
                                      |  Max # Bulkheads (+ FP & AP)       52
                                      |  Max # Longitudinal Increments     40
**************************************|**************************************
1SHIP- BB 35 Original Hull    05/20/11   SERIAL #- 6134  DATE:20-MAY-11 PAGE:   3

                            VESSEL DESIGN CONDITION

 DESIGN DISPLACEMENT          24637.000 TONS SW at DENSITY =     35.000 FT3/TON
 DESIGN DRAFT   (+ ABOVE BL)     26.103 FT |
 DESIGN LCG     (+ FWD MID)      -4.080 FT | DESIGN LCB  (+ F MID)     -4.080 FT
 DESIGN VCG     (+ ABOVE BL)      0.000 FT | DESIGN VCB  (+ ABL)       14.192 FT
 DESIGN TCG     (+ STBD)          0.000 FT | DESIGN TCB  (+ STBD)       0.000 FT
 DESIGN TRIM    (+ BY STERN)      4.647 FT | DESIGN LIST (+ STBD)       0.000 DEG

 LENGTH OVERALL                 565.000 FEET
 LENGTH BETWEEN PERPENDICULARS  565.000 FEET
 LENGTH ON DESIGN WATERLINE     565.000 FEET

 STATION OF MAX AREA (AT DWL)   289.806 FEET FROM FP
 BEAM AT STATION OF MAX AREA     95.296 FEET
 SECTION AREA COEFFICIENT        0.9945
 PRISMATIC COEFFICIENT           0.6155
 BLOCK COEFFICIENT               0.6121

 Specified Tolerances of Volume =0.00001000 and LBP =0.00000500
   Maximum Iterations           =        50

                 Approximate Bounding Cube Values:
       -----------------------------------------------------
        Forward X location              0.000 Ft (+ Aft FP)
        After   X location            565.000 Ft (+ Aft FP)
        PORT    Y value on Station    -79.812 Ft
        STBD    Y value on Station     79.812 Ft
        Lowest  Z value on Station      0.000 Ft (+ Abv BL)
        Highest Z value on Station     53.231 Ft (+ Abv BL)

   KK      3 NO Main Hull INITIAL & INTERPOLATED OFFSETS Printed
   IPLOT  0 NO PLOTS
   NPU      Plots will be SHCP NEUTRAL PLOTFILE unformatted
   PWIDTH   Plotter Width (inches) set to :    30.000
   PBORDR   Plot Border (inches) set to   :     1.000
   POHANG   Fraction of LBP for overhang  :     0.150
   KKAP   0 Print Appendage INITIAL and INTERPOLATED OFFSETS
   IPLTAP 0 NO Appendage PLOTS
   IPLCON 0 Connection from Station ENDS to Centerline & DAE SHOWN
   MSGSAV 0 Do not save HULL/APPENDAGE Evaluation Messages if Successful
   IUNIT  0 Input/Output units selected are ENGLISH-ENGLISH

                  HULL & APPENDAGE PROPERTIES AT DESIGN CONDITION
                                                            +STBD   +ABL    +AFT FP
```

```
   N  R        TITLE                          VOLUME    DISPL    TCB     VCB      LCB
TYPE  SYM
   0 " " Main Hull                      861584.94  24616.7   0.000  14.195  286.485
OFF BOTH
   1     RUDDER                            320.00      9.1   0.000   8.000  548.000
PNT
   2     STARBOARD BILGE KEEL              195.00      5.6  55.000  12.000  282.500
PNT
   3     PORT BILGE KEEL                   195.00      5.6 -55.000  12.000  282.500
PNT
 Hull & Appendage Volume (Ft^3)       862294.94
      Displacement (Tons)                        24637.00
           Transverse Moment (Ft-Tons)                             0.00
                Vertical Moment (Ft-Tons)                             349652.06
                     Longitudinal Moment (Ft-Tons)                            7060473.50

       2649 Entries used in SDT out of a maximum of   4000000
1SHIP- BB 35 Original Hull    05/20/11   SERIAL #- 6134  DATE:20-MAY-11 PAGE:   4
  INFO - The following Point Volumes are close to or exceed volumetric tolerance:
8.62294960
 1 RUDDER                        Volume: 320.000000  Weight: 9.14285755
 2 STARBOARD BILGE KEEL          Volume: 195.000000  Weight: 5.57142878
 3 PORT BILGE KEEL               Volume: 195.000000  Weight: 5.57142878
1SHIP- BB 35 Original Hull    05/20/11   SERIAL #- 6134  DATE:20-MAY-11 PAGE:   5

                          INPUT COMPARTMENT DESCRIPTIONS

  ID        NAME            SYM PERM   X1D    X2D      Y1D      Y2D      Z1D      Z2D
 ROFF

 100 Fwd Boiler Rm B-2       0 0.90 208.00 244.00     NONE    30.00     8.00
28.00   0
 200 Mid Boiler Rm B-3       0 0.90 244.00 276.00     NONE    30.00     8.00
28.00   0
 300 Aft Boiler Rm B-4       0 0.90 276.00 308.00     NONE    30.00     8.00
28.00   0
 400 Stbd Engine Room        1 0.85 356.00 416.00     2.00    30.00     4.00
28.00   0
 450 Port Engine Room       -1 0.85 356.00 416.00     2.00    30.00     4.00
28.00   0
 800 Trim Tank D-12          0 0.95 488.00 518.00     NONE     NONE     4.00
20.00   0
 810 Trim Tank D-13          0 0.95 518.00 540.00     NONE     NONE    10.00
20.00   0
 998  INTACT STABILITY       0 0.10 282.50 283.50     NONE     0.10     NONE
0.10   0
1SHIP- BB 35 Original Hull    05/20/11   SERIAL #- 6134  DATE:20-MAY-11 PAGE:   6

                  DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

 CONDITION    1

  INTACT STABILITY


  FREE FLOODED SPACES INCLUDED:
                                998

 SHIP PROPERTIES BEFORE DAMAGE

    DISPL     LCG  POLE HT    TCB    LIST    TOLVOL    TOLLBP    MAXITER
  24637.00 -4.080  34.84  0.0000   0.000  0.000010  0.000005     20
```

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF
TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	0.000	0.000	14.194	-4.256	26.100	4.783
			5.00	0.417	2.217	14.290	-4.252	26.090	4.727
			10.00	0.859	4.444	14.584	-4.243	26.061	4.551
			15.00	1.371	6.712	15.088	-4.228	26.023	4.237
			20.00	1.952	9.004	15.811	-4.207	25.957	3.786
			25.00	2.631	11.328	16.774	-4.181	25.851	3.183
			30.00	3.242	13.517	17.911	-4.159	25.712	2.638
			35.00	3.359	15.205	18.982	-4.148	25.576	2.419
			40.00	2.997	16.432	19.920	-4.144	25.446	2.431
			45.00	2.279	17.327	20.736	-4.144	25.317	2.566

1SHIP- BB 35 Original Hull 05/20/11 SERIAL #- 6134 DATE:20-MAY-11 PAGE: 7

DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

CONDITION 2

Add Flooding in After Trim Tanks

FREE FLOODED SPACES INCLUDED:
800 810

SHIP PROPERTIES BEFORE DAMAGE

DISPL	LCG	POLE HT	TCB	LIST	TOLVOL	TOLLBP	MAXITER
24637.00	-4.080	34.84	0.0000	0.000	0.000010	0.000005	20

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF
TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	0.000	0.000	14.379	-4.332	26.340	6.965
			5.00	0.442	2.226	14.477	-4.330	26.331	6.918
			10.00	0.909	4.462	14.771	-4.320	26.306	6.757
			15.00	1.446	6.739	15.277	-4.304	26.271	6.468
			20.00	2.051	9.039	16.003	-4.282	26.212	6.060
			25.00	2.753	11.371	16.971	-4.254	26.117	5.507
			30.00	3.348	13.535	18.093	-4.231	26.018	5.108
			35.00	3.456	15.204	19.152	-4.221	25.937	5.078
			40.00	3.089	16.418	20.080	-4.219	25.866	5.323
			45.00	2.373	17.306	20.890	-4.221	25.802	5.725

1SHIP- BB 35 Original Hull 05/20/11 SERIAL #- 6134 DATE:20-MAY-11 PAGE: 8

DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

CONDITION 3

Add Flooding in Both Engine Rooms

FREE FLOODED SPACES INCLUDED:

800 810 400 450

SHIP PROPERTIES BEFORE DAMAGE

DISPL	LCG	POLE HT	TCB	LIST	TOLVOL	TOLLBP	MAXITER
24637.00	-4.080	34.84	0.0000	0.000	0.000010	0.000005	20

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF
TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	0.000	0.000	15.407	-4.503	27.956	12.308
			5.00	0.554	2.248	15.505	-4.500	27.949	12.270
			10.00	1.097	4.472	15.797	-4.487	27.902	12.062
			15.00	1.678	6.707	16.293	-4.464	27.833	11.703
			20.00	2.345	8.985	17.011	-4.434	27.750	11.224
			25.00	3.043	11.237	17.943	-4.403	27.668	10.784
			30.00	3.531	13.234	18.980	-4.383	27.689	10.804
			35.00	3.593	14.796	19.973	-4.376	27.800	11.259
			40.00	3.201	15.928	20.838	-4.378	27.937	12.013
			45.00	2.470	16.749	21.584	-4.384	28.098	12.962

1SHIP- BB 35 Original Hull 05/20/11 SERIAL #- 6134 DATE:20-MAY-11 PAGE: 9

DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

CONDITION 4

Add Flooding in all three Boiler Rooms

FREE FLOODED SPACES INCLUDED:
800 810 400 450 300 200 100

SHIP PROPERTIES BEFORE DAMAGE

DISPL	LCG	POLE HT	TCB	LIST	TOLVOL	TOLLBP	MAXITER
24637.00	-4.080	34.84	0.0000	0.000	0.000010	0.000005	20

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF
TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	0.000	0.000	16.777	-4.347	30.857	8.300
			5.00	0.679	2.253	16.875	-4.343	30.854	8.273
			10.00	1.318	4.455	17.165	-4.339	30.793	8.265
			15.00	1.941	6.617	17.644	-4.328	30.666	8.139
			20.00	2.629	8.805	18.335	-4.311	30.513	7.903
			25.00	3.218	10.853	19.181	-4.302	30.436	7.983
			30.00	3.542	12.605	20.091	-4.302	30.560	8.525
			35.00	3.545	14.024	20.992	-4.310	30.885	9.372
			40.00	3.147	15.062	21.787	-4.321	31.310	10.440
			45.00	2.446	15.818	22.481	-4.336	31.837	11.704

1SHIP- BB 35 Original Hull 05/20/11 SERIAL #- 6134 DATE:20-MAY-11 PAGE: 10

DAMAGED TRANSVERSE STATICAL STABILITY CALCULATIONS

CONDITION 5

Remove Flooding from Port Engine Room

FREE FLOODED SPACES INCLUDED:
800 810 400 300 200 100

SHIP PROPERTIES BEFORE DAMAGE

DISPL	LCG	POLE HT	TCB	LIST	TOLVOL	TOLLBP	MAXITER
24637.00	-4.080	34.84	0.0000	0.000	0.000010	0.000005	20

CHANGE IN TRANS. CENTER OF GRAVITY AFTER RUNOFF
TCG= 0.0000 FOR A SHIFT OF 0.0000 Ft. (+ STBD, - PORT)

NET DAMAGED SHIP PROPERTIES

DISPL	LCG	POLE HT	HEEL	RA	TCB	VCB	LCB	DRAFT	TRIM
24637.00	-4.080	34.84	0.00	-0.635	-0.635	16.152	-4.269	30.056	5.690
			5.00	-0.024	1.602	16.249	-4.267	30.042	5.675
			10.00	0.548	3.784	16.537	-4.264	29.956	5.679
			15.00	1.158	5.973	17.022	-4.257	29.842	5.615
			20.00	1.864	8.212	17.729	-4.245	29.717	5.461
			25.00	2.571	10.395	18.632	-4.237	29.622	5.449
			30.00	3.013	12.274	19.608	-4.237	29.703	5.866
			35.00	3.086	13.768	20.558	-4.247	29.970	6.601
			40.00	2.745	14.864	21.397	-4.261	30.345	7.590
			45.00	2.109	15.681	22.141	-4.277	30.834	8.767

INVALID COMMAND ENTRY: END